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Robert Pernell, Commissioner
Presiding Member, Energy Efficiency Committee
California Energy Commission
1516 Ninth Street, MS 33
Sacramento, CA 95814

In The Matter Of:)
REVIEW OF CONCERNS RAISED BY TYCO ADHESIVES)
ON BUILDING ENERGY EFFICIENCY STANDARDS)
REQUIREMENTS FOR CLOTH BACK RUBBER ADHESIVE DUCT TAPE)

Commissioner Pernell:

In your announcement for the June 14, 2001 workshop, you requested input from the Lawrence Berkeley National Laboratory. We would like to assist the commission in reviewing the comments of Tyco Adhesives by summarizing our relevant work in this area and relating it to the concerns raised.

My name is Max Sherman. I am a Staff Senior Scientist, Ph.D. and Group Leader at the Lawrence Berkeley National Laboratory. I am and have been the Principal Investigator for work on residential thermal distribution systems at LBNL and specifically for the sealant longevity work of concern to Tyco adhesives. These comments were prepared by myself and Dr. Iain Walker, who is the project manager for our sealant longevity testing efforts as well as other duct-related activities.

Background

Our work related to the issues of California ducts began in 1990 and was funded by State utilities through the California Institute for Energy Efficiency. CIEE, like PIER, is concerned with public interest energy R&D to benefit the State. In addition to CIEE and PIER funding we have received funding from the US Department of Energy and Environmental Protection Agency to advance the issue of residential thermal distribution systems.

Our earliest efforts focused on characterizing the impact of thermal distribution losses on the efficiency of California houses. When it became apparent that there was significant potential for savings, we began to investigate ways of better quantifying the problem and also of solving the problem for both new and existing houses.

Our characterization work showed that ducts in California waste about 20-40% of the energy that flows through them. The biggest single reason for this loss is duct leakage. Our data shows that a typical California house loses 17% of the air handler flow, which goes outside rather than to the house (and also 17% comes from outside into the return ducts rather than from the house).

Duct leaks are caused by either failed or non-existent seals at joints, plenums, boots or other fittings. In the stock of houses, conventional duct tape appears to be the most common sealant. It is quite common to see failed duct tape[1] when examining the duct systems in existing houses. Other tapes exist and are recommended by their manufacturers for use on thermal distribution systems, normally using other adhesives.

[1] (We are using the term “duct tape” to refer to common cloth-backed, rubber-adhesive product.

Sealant Longevity Testing

The common observation that many tape products failed in the field led CIEE and its partners to want a way of rating the longevity of different technologies in order to recommend superior products in both new and retrofit applications. In the mid 90s LBNL was tasked to develop a test method and evaluate a wide range of existing and proposed duct sealant technologies.

The test method we set out to develop would require accelerated testing to be practical. While it is difficult in such accelerated testing to convert lab performance to actual field performance, it is possible to develop relative ratings and recommendations.

The method we developed is described in several of the references below, but is essentially stresses the products with extreme, but not abnormal limits of temperature pressure and application. We apply each product to a standardized joint and subject it to changing temperatures and pressures while measuring the leakage of the joint. All of the sealants we used are rated to at least 200 ºF and we keep the maximum temperature of testing below 180 ºF, which is a maximum temperature a duct system is likely to see at a hot heat exchanger or a very hot attic.

We tested a sample from each of the product types intended for sealing ducts. Most of the products were tapes of some kind or another, but we also tested mastic-based sealants and the aerosol sealant we had developed. The most common kind of tape was conventional duct tape and we tested many varieties of duct tape, but we also tested acrylic-adhesive tapes, butyl-adhesive tapes, foil-backed tapes, etc.

The intent of our testing was to find a rating for different sealants, instead what we found was much simpler. Virtually all of our duct tape samples failed in a few days and were replaced with a new sample. No other kind of sealant failed at all, including the other tape variants. (Typically after 90-100 days of accelerated testing we would stop the test and replace any unfailed samples with another kind.)

The test joint we have used is a 90º joint similar to that found when a duct meets a plenum or connector. This represents a tougher test for a seal than a flat-to-flat joint would, so we believe it is more appropriate for an accelerated test as failures would happen sooner than for a simpler joint. Some tape manufacturers recommend that such a joint only be done with a collar holding the tape in place. We did not test with such a collar because we not seen collars used in the field and because we would no longer be testing the sealant, but rather the collar.

We published the first results of this testing in 1998. In August of 1998 we held a workshop at the ACEEE Summer Study to explain and share our results. The participants of the workshop were not at all surprised about our results as most of them reported finding significant duct tape failures in the field. One attendee, Jerry Serra of Tyco, was surprised to hear these reports.

The first results published were from our Mark I test apparatus and included about 30 individual tests. After the first round of testing was completed, the Department of Energy funded us to build a Mark II apparatus that allows more flexibility in testing. We can test more samples in different configurations faster and have tested about 50 different samples. Our results, however, mirror the first set of results in that only duct tape fails.

The Mark II apparatus has also allowed us to test the flat-to-flat joint with three good wraps of tape around it. Although not always done in the field, we are testing a flat-to-flat seal that has three good wraps of tape around it, as is sometimes recommended. Although this testing has only recently started, we are beginning to see deterioration of the duct tapes in this configuration as well.

Underwriters Laboratory (UL) Standards

Underwrites Laboratory writes standards that apply to duct tape. Specifically UL181B-FX applies to tape products used on ducts. Many of the tape products we tested had passed this standard. We did not find any significant correlation between whether a tape had a UL 181 rating and how well it did on the test rig.

This lack of correlation is not surprising as the UL 181 tests are not intended to look at longevity. The test itself is a suite of tests that look at fire safety, mechanical strength, stretching, etc. The closest the suite has is a test for initial adhesion.

We approached UL about adding a longevity test to their 181 suite. They indicated that preferred to include only consensus test methods, such as through ASTM, as part of their tests and encouraged us to work with such a group to develop a test method.

The UL 181 standard may be useful for safety and quality control reasons, but without a longevity component to it, it is not a good predictor of how well a tape will perform from an energy efficiency perspective.

American Society of Testing and Materials (ASTM)

We approached ASTM Committee E6 on building constructions and they indicated that they would be interested in working toward a new standard on longevity testing. To that end we have been leading a task group of interested parties, which has included representation from Tyco. The standard was initially based on the test method we used at LBNL, but it has been modified by task group efforts and input from commentors over the course of the last couple of years.

The ASTM process is deliberative, but good progress is being made. There are many rounds of balloting in an attempt to reach the best consensus. On the last round of balloting there were only two negative votes (out of a large number of votes), one of which was from Tyco. This low number of negative votes is indicative that the standard is heading toward completion. Small changes to the standard are being made to respond to the comments and it will move forward to the next level of balloting.

Conclusions and Recommendations

- The use of cloth back, rubber adhesive tapes on typical duct systems in California will be likely to fail prematurely. Our tests support the Commission decision to separate these products out from the other duct sealant systems and give them special treatment.
- A UL 181 rating is not a good predictor of whether tapes will fail prematurely or not. While the Commission may wish to require a UL 181 rating for other reasons, it is not an adequate replacement for a requirement relating to longevity of the duct seal.

- For future standards the Commission should adopt a longevity performance criterion rather than a prescriptive criterion to allow the sealant industry to develop innovative products. A test similar to the proposed ASTM standard could be used to determine such ratings.

Thank you for giving us the opportunity to provide you with background information. We intend to attend your workshop on June 14, 2001, and would be happy to answer any questions at that time. I have attached supporting information to this memo including a list of references with more detailed information as well as some responses to concerns raised about LBNL's quality of research.

Sincerely,

Max H. Sherman, Group Leader, Energy Performance of Buildings Group, LBNL

CC:
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APPENDIX: SUPPLEMENTAL MATERIAL

The material in the section is in response to concerns raised by various organizations regarding the quality of research at LBNL and the objectivity of LBNL researchers and the appropriateness of the work.

Aerosol Sealant

Some parties have suggested that LBNL research results relating to the use of duct tape in new construction have been biased because of our connection to the aerosol sealant technology currently being commercialized by Aeroseal Inc. To assuage any concerns in this area, this section summarizes the history and status relating to the aerosol sealant technology.

When it became clear in the early 1990s that duct leakage was important in existing California houses, CIEE tasked LBL to investigate technologies for sealing leaky ducts. Because of the laborious and unpleasant aspects of conventional in-situ duct sealing, we focused our research on developing an internal access technology. Remote taping, robotic foaming and other such techniques were investigated, but we settled on a technology for dispersing sticky aerosol particles in the duct in such a way that they would stick to the edges of leaks and build up to a seal.

The development required a lot of laboratory science to find materials, particle sizes, and retrofit protocols that could work in real situations. The science was of sufficient quality that it lead to at least one specific Ph.D. and the technology was sufficiently unique that LBL was awarded a patent for aerosol sealing.

Although LBL owned the patent and a right to use the technology in research, CIEE and its partners owned the exclusive right to license the technology. Their objective was to do so in order to maximize the penetration of this technology and thereby its benefit to California ratepayers.

CIEE solicited and considered many options for how to license the technology. In the end they elected to do so by contracting with Aeroseal Inc, which had one of the inventors, Mark Modera, as CEO and part owner. Mark Modera now works 50% time for Aeroseal and 50% time for LBNL.

Because of the perceived conflict of interest, Mark Modera's responsibilities related to residential thermal distribution project management have been phased out. Specifically, he has never been involved in any of the sealant longevity work.

Our first longevity tests of any kind were funded by EPA to measure the longevity of the aerosol sealant. We used that experience to help develop the Mark I apparatus. We have always tested the aerosol sealant in our recent tests, just as we test other sealant approaches including tapes and mastics.

LBNL does not have any kind of equity position in Aeroseal Inc. LBNL's only monetary connection the Aerosol sealant is through a complex royalty sharing arrangement. The royalty amount returned to the research group is rather nominal; the only individuals who get royalty payments are the inventors and they are not involved in any of this decision making.

Finally, the aerosol sealant was not developed as an alternative to sealing new duct systems with traditional means. Its value is primarily for retrofit applications, but it can, in principle, be used in new construction.

Longevity Apparatus Test Configuration

Some parties have suggested that our testing protocol is inappropriate and leads to flawed results. I have listed some of the issues raised and responded to them:

- ***"The joint being tested is not representative"*** The joint tested in the LBNL protocol is a round to flat joint. It is probably the most common type used in the systems using flex-duct, which is the dominant style in new California construction. Even in sheet-metal ducting, this type of connection is used frequently. The joint was chosen as the most stringent case of those typically found in real construction.

- ***"Temperature cycling is not representative"*** It is true that no ducts are exposed to six minute cycles going from below freezing to above 150F. The purpose of the cycling is to accelerate whatever failure modes exist in order to get ratings in a reasonable amount of time; LBNL has not attempted to convert these times into estimates of lifetime in actual use. It should be noted, however, that the temperature cycling to low temperatures was included in order to accelerate failures in non-tape sealant systems. Duct tapes actually fail faster when subjected to sustained high temperatures.

- ***"The test protocol puts undue mechanical stress on the tapes."*** There is stress put on the tape because it must make a right angle seal and because there is air pressure representative of a supply duct system. These are completely representative of real world installations. Following the Uniform Mechanical Code, there is no stress on the tape from the joining itself as the two pieces of sheet-metal are screwed together.

Although it is code, this type of connection is often not found in field as installers make use of the superior mechanical strength of duct tape instead. Similarly, the sheet-metal is cleaned before installation to remove any dirt any oil present; such cleaning is very difficult to achieve in real world environment. Because of these last two points, the test conditions are actually more favorable than one might expect.

- ***"The procedure does not require a clamp during testing."*** This statement is correct. UL 181B-FX and some manufacturers recommendations require that tapes be clamped in a specific way. We are not evaluating the UL standards or manufacturers recommendations; rather we are developing a performance test for sealant longevity in the configurations actually used. Even if such clamps were routinely used, testing using a clamp would defeat the purpose of the test because the clamp would keep the seal, even if the sealant did not.

American Society of Testing and Materials

LBNL leads a task group at ASTM developing a sealant longevity test method. Some parties have suggested that LBNL is using this position to bias the test and, alternatively, that ASTM has rejected the test method due to poor quality research.

LBNL elected to submit the longevity test to ASTM in order to increase consensus. ASTM is certified by the American National Standards Institute to write American National Standards. The process ASTM uses is that a task group drafts the standard and it much pass three levels of scrutiny involving

wider and wider audience and cannot be approved until all negatives have been addressed.

The ASTM process usually takes several years for a new standard and along the way many negative votes are cast until consensus is reached. The sealant longevity test method is following a normal course at ASTM; the method is simpler than the methods used at LBNL, but similar in approach. These changes have been made due to the comments of many interested parties including Tyco. ASTM, rather than LBNL, has control of this process.

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